FISHERY DATA SERIES NO. 107

ABUNDANCE ESTIMATES OF THE ESCAPEMENT OF CHINOOK SALMON INTO THE KENAI RIVER, ALASKA, BY ANALYSIS OF TAGGING DATA, 1988[1]

By

Jay Carlon
and
Marianna Alexandersdottir

Alaska Department of Fish and Game
Division of Sport Fish
Juneau, Alaska 99802

March 1989

[1] This investigation was partially financed by the Federal Aid in Sport Fish Restoration Act (16 U.S.C. 777-777K) under Project F-10-4, Job No. S-32-2.

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ABSTRACT

Drift gill nets were used to capture adult chinook salmon *Oncorhynchus tshawytscha* in the lower Kenai River for tagging. Tagged fish were recovered during a creel survey of the recreational fishery. The number of chinook salmon entering the Kenai River from 20 May to 28 July was estimated using the tag release-and-recapture data. Effort and catch data from the drift gill nets were used to estimate the abundance of chinook salmon from 29 July to 11 August. The estimated total return of chinook salmon to the lower Kenai River from 20 May to 11 August was 135,916. The abundance of late-run fish (110,869) was four times that of early-run fish (25,047). The major age group of returning chinook salmon was 1.4 (75 percent). The mean length-at-age of male and female chinook salmon increased throughout the return.

KEY WORDS: Kenai River, chinook salmon, *Oncorhynchus tshawytscha*, tag release-and-recapture, abundance estimate, gill net effort and catch statistics, age-sex-length compositions.

INTRODUCTION

Alaska's largest recreational fishery in fresh water occurs in the Kenai River. More than 320,000 angler days of effort were expended in this fishery in both 1985 and 1986 (Mills 1986, 1987) and nearly 290,000 angler days were expended in 1987 (Mills 1988). Most of the effort by anglers is directed at returning chinook salmon *Oncorhynchus tshawytscha* and occurs during June and July in the mainstem of the river downstream from Skilak Lake (Figure 1). In 1988, both estimated angler-effort and harvest of chinook salmon by this fishery were the largest since a creel survey of the fishery was begun in 1977 (Hammarstrom in press) (Figure 2). Fishing effort is expected to continue to increase because the Kenai River is near a major population center and is easy to access.

The Kenai River has two stocks of chinook salmon: (1) an early run which enters the river from mid-May until late June; and (2) a late run which enters the river from late June through early August. Fish from both stocks are highly valued by anglers because of their large size, especially fish from the late run. Chinook salmon in the late run average about 18 kg (40 lbs) and often exceed 36 kg (80 lbs). The world record for a sport-caught chinook salmon was taken from the Kenai River in 1985; it weighed 44 kg (97 lbs).

Management of the recreational fishery in the Kenai River is complicated by the relatively large harvests of chinook salmon by sport and commercial fisheries in the marine waters of Cook Inlet, particularly by the commercial set net fishery along the east side of the Inlet (McBride et al. 1985). Estimates of the abundance and biological characteristics (age and sex compositions, mean length at age) of the escapement are needed to effectively manage the sport fishery. The Sport Fish Division of the Alaska Department of Fish and Game (ADF&G) proposed a tag release-and-recovery program in 1975 to provide the required estimates. Electrofishing equipment, drift gill nets (Hammarstrom 1980), fish traps, and fish wheels (Hammarstrom and Larson 1982, 1983, 1984) were tested as methods for catching chinook salmon. Drift gill nets were found to be the most effective and were used to estimate abundance of late-run chinook salmon in 1984 (Hammarstrom et al. 1985), 1985 (Hammarstrom and Larson 1986), 1986 (Conrad and Larson 1987), and 1987 (Conrad 1988). The abundance of early-run chinook salmon was estimated in 1985 (Hammarstrom and Larson 1986), 1986 (Conrad and Larson 1987), and 1987 (Conrad 1988). Improvements to equipment and tagging techniques increased the number of fish tagged each year, while improved data collection procedures and more tag recovery personnel working in 1985 through 1987 increased the number of sport-caught fish examined for tags. Similar procedures were used in 1988 to assure appropriate sampling levels for developing abundance estimates.

The feasibility of using hydroacoustics (i.e. sonar) to estimate inriver return has been investigated since 1984 and the first estimates were produced in 1987 for the late run of chinook salmon and in 1988 for the early run. The gear samples a large fraction of the time-space window for chinook salmon. In 1987, the tagging and sonar estimates only differed by 17% for the late run (Conrad 1988).

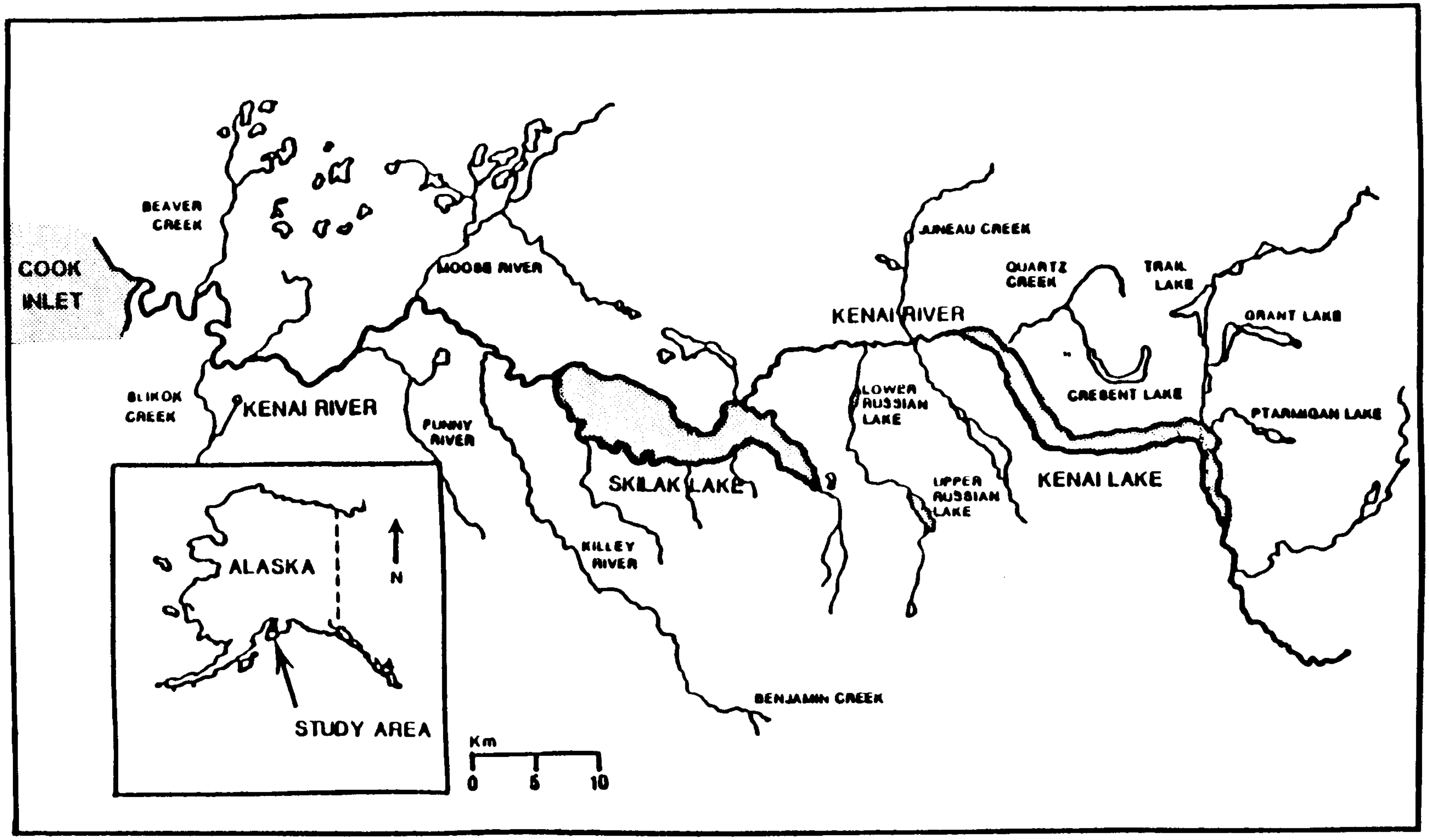


Figure 1. Map of the Kenai River system.

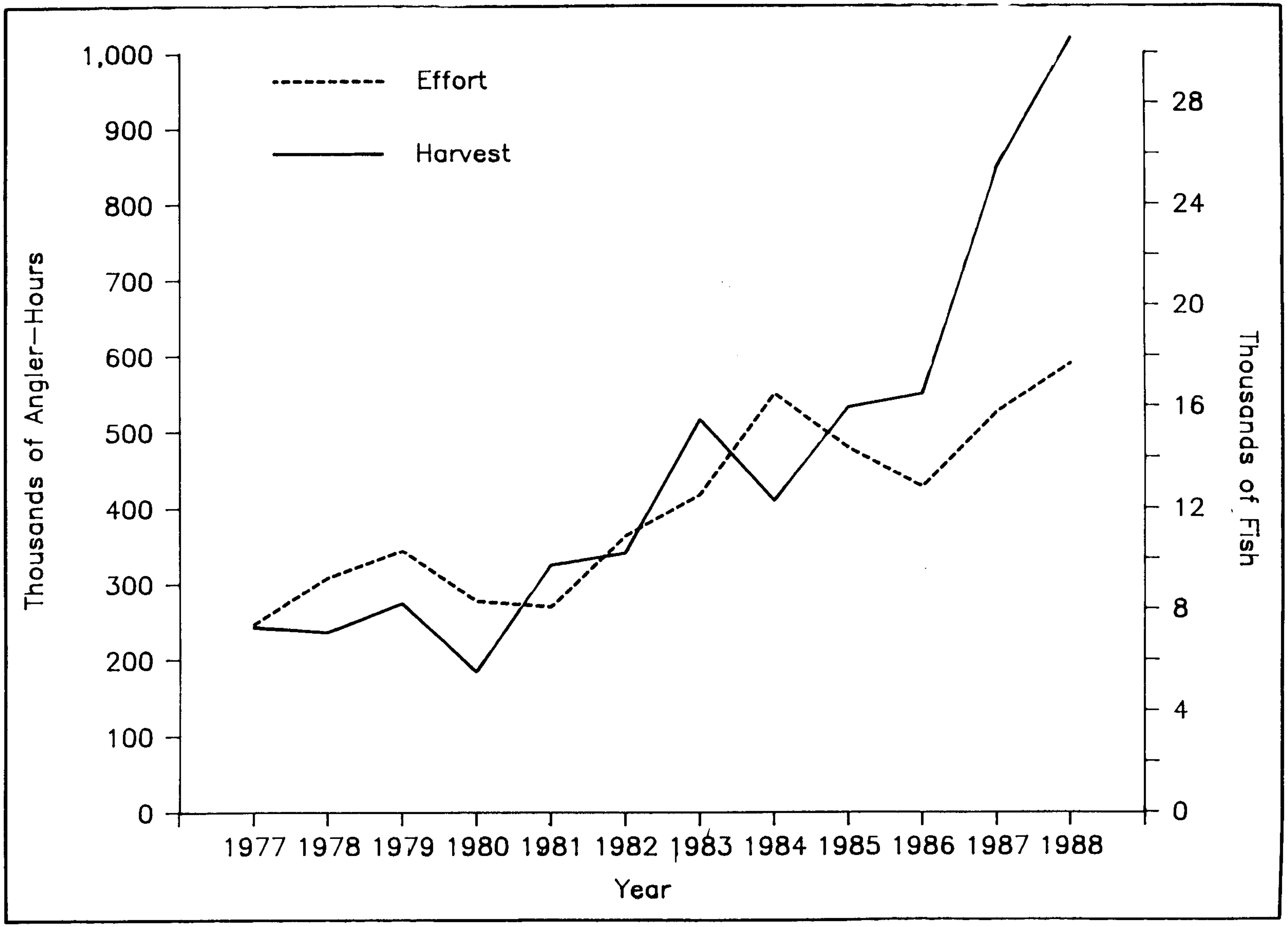


Figure 2. Estimates of angler-effort and harvest of chinook salmon for the recreational fishery in the Kenai River, 1977 - 1988.

In the fall of 1988, the Board of Fisheries made the decision to separate the early and late run arbitrarily at July 1 for the purpose of in-season management. Although the definitions of the early run (20 May to 30 June) and the late run (1 July to 11 August) are convenient representations of the timing of the runs, in reality there is overlap of their timing. The gradual change in the mixture of early-run and late-run fish in the return is evidenced by the increasing mean length for all sex-age groups throughout the season in the gill net and recreational harvest samples (Conrad and Larson 1987, Conrad 1988). The larger mean size-at-age of late-run fish compared to early-run fish has been documented previously (Burger et al. 1985, McBride et al. 1985).

This report describes the methods used to estimate the number of chinook salmon in the escapement to the Kenai River during 1988. In addition to an abundance estimate, biological data from chinook salmon sampled during tagging and spawning ground surveys are presented. These data, in conjunction with estimates of numbers of fish by age for the recreational harvest (Hammarstrom in press), are used to estimate the numbers of fish by age in the spawning population. These data are an integral part of the long-term database of total return information, which in future will be used to estimate and monitor spawner-return relationships.

METHODS

Tagging

Four, two-person crews tagged chinook salmon. Tagging was conducted between 11 and 15 km upstream from the mouth of the Kenai River (Figure 3) each day from 20 May through 11 August, inclusive. Two crews usually operated on 4 days of each week and all four crews operated on the remaining 3 days of each week. However, when four crews were on duty at the same time, one crew performed gear maintenance tasks and was not involved in capturing and tagging fish; the maximum number of crews fishing at any one time was three. This was an attempt to eliminate the effects of inter-crew competition on catch and effort statistics. Inter-crew competition had an effect on catch and effort statistics in 1986 (Conrad and Larson 1987), but not in 1987 (Conrad 1988).

Sampling could be conducted during daylight hours only and was restricted to the 9 hours before high tide because catches of chinook salmon were highest during this period in other years (Hammarstrom and Larson 1982, 1983, 1984). The efficiency of the drift gillnetting technique is greatly reduced by the high river levels and reduced river velocities encountered near high tide. Two crews worked each tide on days when two high tides occurred during daylight. When only one high tide occurred during daylight, either two or three crews operated depending on crew availability. Each sampling period was about 6.5 hrs long.

Each crew used a 19 cm stretched-mesh drift gill net about 15 m long to capture chinook salmon. The net was set from the bow of an outboard powered

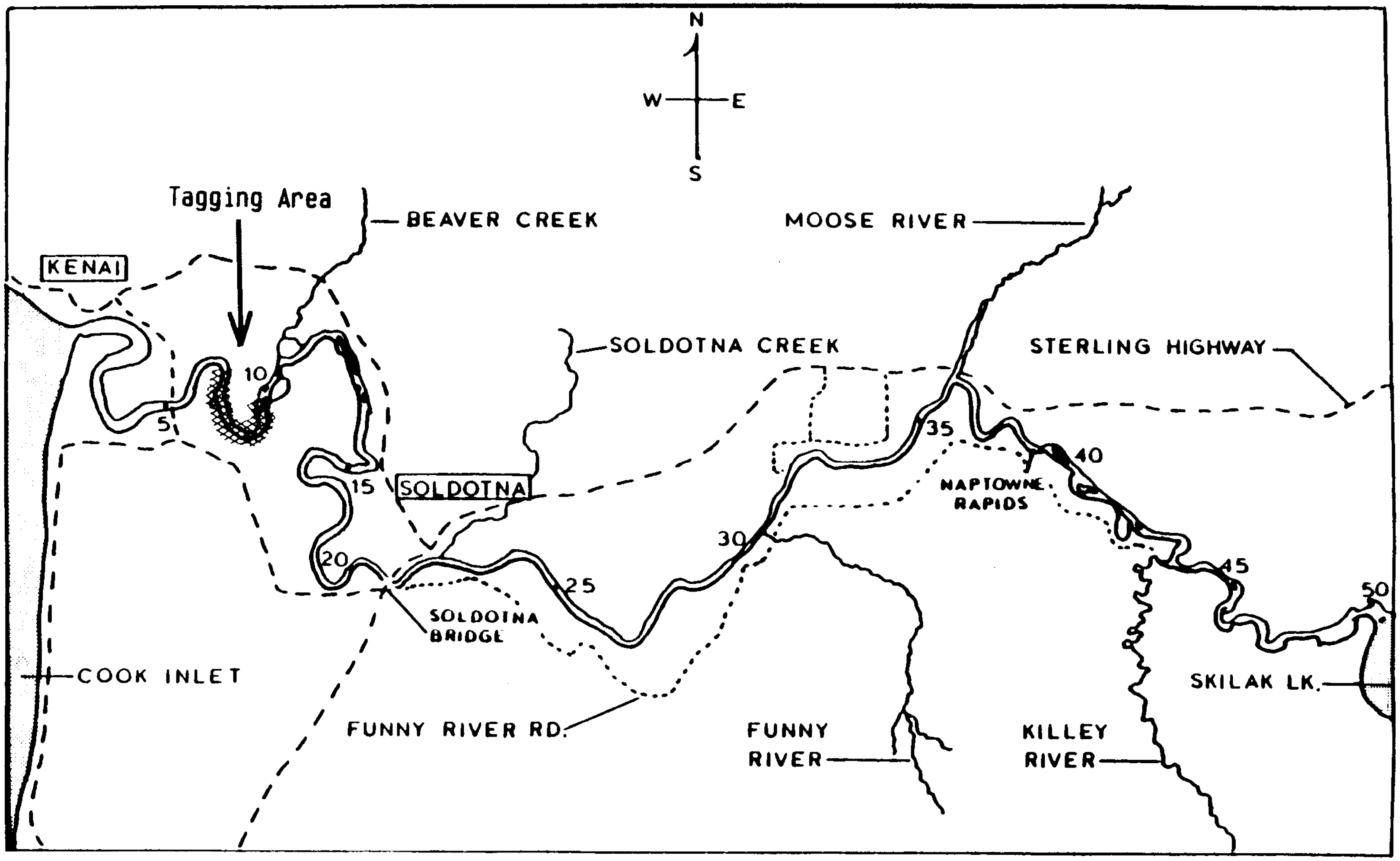


Figure 3. Map of the lower Kenai River between Cook Inlet and the outlet of Skilak Lake.

skiff by releasing one end of the net near the shoreline and rapidly backing the skiff toward the middle of the river channel. Once the net was extended, it was allowed to drift downstream with the current until either a fish was caught, the net encountered a snag on the river bottom, or the boundary of the tagging area was reached.

When a fish became entangled in the net, the floats on the net bobbed violently and the net was then immediately retrieved. A soft, braided rope was looped around the caudal peduncle of each chinook salmon captured. The fish was then untangled from the net and slipped into a cradle for processing. The tagging cradle was a rigid, foam-padded device which hung from the side of the skiff with its base about 15 cm below the water line. The cradle immobilized the captured fish and kept it in the water during processing. The date, time of capture, and approximate river mile of capture were recorded for each chinook salmon brought to the skiff, in addition to the tag number for fish tagged.

The condition of each captured chinook salmon was assessed prior to tagging. Chinook salmon with deep scars, damaged gill filaments, a lethargic condition, or fish requiring extended processing time were not tagged. Fish were tagged with individually numbered Floy FT-4 plastic spaghetti tags cut to 50 cm lengths. A different tag color was used during each approximate 2-week temporal stratum. Identifying each release stratum with a different tag color allowed tags recovered with no recorded tag number (due to an omission by the creel survey technician) to be associated with a release stratum for the abundance estimate. The following tag colors were used during the specified temporal strata:

green	-	20 May	through 31 May,
white	-	1 June	through 14 June,
orange	-	15 June	through 30 June,
yellow	-	1 July	through 15 July,
blue	-	16 July	through 1 August,
red	-	2 August	through 11 August.

Each tag was inserted below the posterior insertion of the dorsal fin with a large needle and secured with an overhand knot. The mid-eye to fork-of-tail length (measured to the nearest 10 mm) and the sex (identified from inspection of external characteristics) of tagged fish were recorded. Three scales were removed from the preferred area (Clutter and Whitesel 1956) of each chinook salmon and mounted on an adhesive-coated card.

Effort and catch for each set with the gill net were recorded. Effort was measured as the number of minutes the net drifted before being retrieved and catch as the number of chinook salmon caught. Captured chinook salmon were tallied according to five categories: (1) untagged fish which were captured and tagged; (2) untagged fish which were captured but not tagged because of a poor condition; (3) fish which were captured and positively identified as chinook salmon but escaped before being processed; (4) previously tagged fish which were recaptured; and (5) fish with healed adipose finclips. Any chinook salmon with a healed adipose finclip was sacrificed so that the head could be inspected for the presence of a coded-wire tag (CWT). The tag numbers of fish in category four were recorded.

Tag Recovery

The inriver, recreational fishery, which is restricted by regulation to the area between the outlet of Skilak Lake and Cook Inlet, was the mechanism for tag recovery. A creel survey of the fishery was used to estimate the proportion of chinook salmon in the river that were tagged. Nearly all sport fishing in the Kenai River occurs upstream of the area where the tagging occurred. The fishery and the creel survey are described in detail by Hammarstrom (in press).

The creel survey was conducted in the downstream (Cook Inlet to Soldotna Bridge) and upstream (Naptowne Rapids to the outlet of Skilak Lake) sections of the Kenai River (Figure 3). In 1988, approximately 84% of the angler-effort and 93% of the chinook salmon harvest occurred in the downstream section (Hammarstrom 1989). The downstream section was surveyed between 17 May and 31 July and the upstream section was surveyed from 3 June to 31 July.

Anglers were interviewed for effort, harvest, and catch rate information primarily at seven popular boat landings in the downstream section:

1. Soldotna Bridge (RM 21.5),
2. Centennial Park (RM 20.5),
3. Poacher's Cove (RM 17.5),
4. King Run resort (RM 15.0),
5. Big Eddy jetty (RM 14.0),
6. Big Bend campground (RM 13.9), and
7. Eagle Rock (RM 11.5).

Two access-site creel survey technicians were primarily responsible for obtaining interview data at these seven sites. Additional angler interviews were collected as time permitted at these sites by two roving creel survey technicians who were primarily responsible for obtaining the boat angler counts necessary for estimating effort.

An additional roving creel survey technician was responsible for obtaining interview data in the upstream section from completed anglers at two launch sites (Bing's Landing, RM 39.5; Dot's Landing, RM 44.0) and incompleted anglers fishing the mainstem between River Miles 39.5 and 50.0. In addition, this technician collected completed trip angler interviews at two launch sites in the midstream section in an attempt to increase the sample size of numbers of fish examined for tags.

The following information was recorded for each angler interviewed: (1) completed-trip or incomplete trip angler; (2) guided or unguided angler; (3) number of hours spent fishing; (4) number and species of fish retained; (5) number and species of fish released; (6) docking location; and (7) number of chinook salmon present with a tag or a tagging wound in the event of tag loss. In addition, the following information was recorded for tagged chinook salmon: date and time of capture, location of capture, and tag color and number. Untagged chinook salmon were inspected for the presence of a tagging wound.

Spawning Ground Surveys

Carcasses from spawning grounds on the mainstem of the Kenai River were sampled to estimate age, sex, and length compositions. Three areas were surveyed: (1) from Cook Inlet to Soldotna Bridge was surveyed from 18 September to 26 September; (2) from the upstream end of Naptowne Rapids to the outlet of Skilak Lake was surveyed on 27 September; and (3) the inlet of the mainstem river to Skilak Lake was surveyed on 28 September (Figure 3). The mainstem is the primary spawning area for late-run chinook salmon (Burger et al. 1985).

All carcasses observed during the surveys were measured for mid-eye to fork-of-tail length (measured to the nearest 10 mm), the sex was identified, and three scales were removed from the preferred area and mounted on an adhesive-coated card. The number of any tag present and the presence/absence of a tagging wound were also recorded. The body cavity of all chinook salmon carcasses was cut open to prevent duplicate sampling and to determine the proportion of unsuccessful spawners.

Analyses

There were three sets of data analyzed: (1) the chinook salmon tag release-and-recovery data; (2) the effort and catch data from the gill nets used to capture the chinook salmon; and (3) the biological data collected during tagging and surveys of the spawning grounds.

Abundance Estimate Using Tagging Data:

The hypothesis that recovery rates of tagged chinook salmon by the two creel surveys (upstream roving survey and downstream access-site survey) were equal was tested with a chi-square statistic. The numbers of tagged and untagged chinook salmon observed by each survey were compared.

In order to determine if the gear used in tagging and recovery samples was size-selective, two hypotheses were tested. The first states that there is no difference between the length distribution of fish at release and tag recaptures. The second hypothesis states that there is no difference between the length distribution of the release sample and recovery samples. These hypotheses were tested using a Kolmogorov-Smirnov two-sample test to compare the length distributions.

Constant probabilities of capture at times of tagging and recapture are important assumptions necessary for Petersen-type abundance estimates (Seber 1982). When tagging and recovery occur over an extended period of time these assumptions are often violated. The tagging data were tested to determine if they were consistent with these assumptions. Two chi-square tests described by Seber (1982, pages 438-439) were used to test these hypotheses. The first tests whether the rate of recovery is equal for all release strata and the second whether the ratio of tagged-to-untagged fish is equal for all recovery strata. If one or both of these tests were significant then a stratified population estimator was used (Darroch 1961). When there are equal numbers of release and recovery strata, the stratified estimator ($\underline{W}$) is (Seber 1982):

$$\underline{W} = D_u M^{-1} \underline{a} \qquad [1]$$

where:

$\underline{W}$ = a vector with the estimates of the number of <u>untagged</u> chinook salmon in each tagging stratum <u>just after the release of the tagged fish</u>,

D_u = a diagonal matrix of the number of untagged fish observed in each recovery stratum *j*,

M = a matrix of m_{ij}, the number of tagged fish in each recovery stratum, *j*, which were released in tagging stratum *i*, and

$\underline{a}$ = a vector of the number of tagged fish released in tagging stratum *i*.

The number of chinook salmon in each stratum at the time of tagging is the sum of the estimated number of untagged fish present and the number of tagged fish released during the stratum. The variance-covariance matrix of $\underline{W}$ was estimated using equations 11.20-11.23 on page 441 of Seber (1982). The variance of the point estimate for the total number of chinook salmon present is the sum of the variance and covariance estimates for the individual strata.

Assumptions necessary for the abundance estimates are (Seber 1982):

1. All chinook salmon in the j^{th} recovery stratum, whether tagged or untagged, have the same probability of being harvested (caught and kept) by the recreational fishery.

2. Tagged fish behave independently of one another with regard to moving among strata and being caught.

3. An angler is as likely to release a tagged chinook salmon as an untagged fish.

4. There is no tag loss, either naturally or by anglers removing tags from chinook salmon which they catch and subsequently release.

5. All tagged fish are recognized as such during recovery.

6. There is no tagging induced mortality.

The estimate of chinook salmon abundance from the analysis of the tag release-and-recovery data was for the period 20 May through 28 July. Three temporal strata for the tagging estimate were defined so that separate estimates for the early and late runs could be generated and the algebraic conditions necessary for the stratified estimator were met. Other temporal stratifications were possible and several were examined to determine how sensitive the estimates and their variances were to different stratifications. Seven alternate stratifications were generated and the point estimate and variance of each calculated using the procedures described previously.

Abundance Estimate Using Gill Net Effort and Catch Data:

To estimate the number of fish that entered the river from 29 July through 11 August, the relationships between effort and catch statistics from the drift gill nets and the abundance estimates were examined. Seventeen statistics were investigated including the traditional measures of fishing success (Table 1). These statistics had been examined previously in 1986 and 1987 (Conrad and Larson 1987, Conrad 1988).

In 1986, effort and catch statistics collected by all four crews working a single tide were excluded from the analysis because of gear competition (Conrad and Larson 1987). However, gear competition did not have a significant effect on the statistics in 1987 (Conrad 1988) or in 1988 (Appendix A). The data from all sets by all crews were used to estimate the statistics for each of the four tagging (temporal) strata because there were very few significant differences for the 13 effort/catch statistics having between-crew variation. Those fish recaptured on the same day that they had been tagged were excluded from compilation of the catch statistics. The linear correlations between the statistics and the estimated abundance of chinook salmon were then calculated.

Only three strata were defined for the estimates of chinook salmon abundance in 1988. To increase the number of data points used to estimate a relationship, the relationship between estimated abundance and the effort/catch statistics was assumed to be the same for all years, and by combining the data from the drift gill nets (Conrad and Larson 1987, Conrad 1988) the number of points used to estimate the relationship increased from four to nine. The number of days in the strata varied considerably (from 10 to 28 days), so to standardize abundance for each stratum, the estimated abundance of chinook salmon for each stratum was divided by the number of days in the stratum for a mean number of fish present per day.

The eight statistics with the highest correlation were used to build linear, power, and exponential models describing mean chinook salmon abundance per day as a function of the effort/catch statistic. The models were (Zar 1974):

for the linear model, $$Y = aX + b, \quad [2]$$

for the power curve, $$Y = aX^{b}, \text{ and} \quad [3]$$

for the exponential curve, $$Y = ae^{bX}, \quad [4]$$

Table 1. Definition of the effort and catch statistics analyzed.

	Acronym	Definition
1.	TOTSETS	The total number of drift gill net sets made during a stratum.
2.	TOTEFF	The total number of minutes of gill net effort during a stratum.
3.	MNDUR	The mean duration (in minutes) of the gill net sets during a stratum.
4.	TOTCAT	The total catch of chinook salmon during a stratum.
5.	MNCAT	The mean catch of chinook salmon per gill net set during a stratum.
6.	MNCPUE	The mean of the individual set CPUE during a stratum.
7.	CPUE	The quotient of the total catch of chinook salmon and the total effort during a stratum.
8.	TOTEFF=0	The total number of minutes of effort by sets which caught no chinook salmon during a stratum.
9.	MNDUR=0	The mean duration in minutes by sets which caught no chinook salmon during a stratum.
10.	%EFF>0	The percent of the total effort (in minutes) during a stratum by sets which caught at least one chinook salmon.
11.	SETS>0	The total number of drift gill net sets which caught at least one chinook salmon during a stratum.
12.	%SETS>0	The percent of the total number of sets that caught at least one chinook salmon during a stratum.
13.	MNDUR>0	The mean duration in minutes of sets which caught at least one chinook salmon during a stratum.
14.	SETS/CD	The mean number of sets per crew-day[1] during a stratum.
15.	EFF/CD	The mean number of minutes of effort per crew-day during a stratum.
16.	CAT/CD	The mean catch of chinook salmon per crew-day during a stratum.
17.	SETS>0/CD	The mean number of sets per crew-day that caught at least one chinook salmon during a stratum.

[1] Statistics defined in Table 1.

where, Y is the estimated mean abundance of chinook salmon per day, X is the effort/catch statistic, and *a* and *b* are regression coefficients. Procedure NLIN of SAS (Sas Institute, Inc 1982) and the Marquardt method of minimizing the error sum-of-squares were used to calculate least-square estimates for the parameters of the nonlinear models. The mean squared error and parameter estimates of the models were examined to select the model to estimate the number of chinook salmon entering the Kenai River from 29 July to 11 August (stratum 4).

The variance of the estimate of abundance for stratum 4 was estimated empirically by Monte Carlo simulation. Rubinstein (1981) describes a procedure for generating values from random variates with a multinormal distribution using the variance-covariance matrix of the variates. The regression parameters (a and b) represent a vector of random variates and, using the variance-covariance matrix for a and b supplied by procedure NLIN, 1,000 new estimates of the regression parameters are generated. These were then used to generate 1,000 estimates of abundance using the value of the effort and catch statistic for stratum 4. The variance for the estimate of chinook salmon abundance for stratum 4 was then calculated empirically from the 1,000 estimates.

Biological Data:

The age compositions of the chinook salmon tagged and those sampled during spawning ground surveys were estimated from the scale samples collected. The biological data were separated into bimonthly periods. Letting p_{ghj} equal the proportion of the sample from time period j belonging to sex g and age group h, the variance of p_{ghj} was estimated by (Scheaffer et al. 1979):

$$V(p_{ghj}) = p_{ghj}(1-p_{ghj})/(n_{Tj}-1), \qquad [5]$$

where, n_{Tj} is the number of legible scales read from chinook salmon sampled during period j. A chi-square test was performed on the numbers assigned to each of the major age groups for time periods in each run (early run and late run) to determine if there were significant changes in age composition during a run. The age compositions of each sex were tested separately.

Mean length at age by sex and its variance were estimated using standard procedures for normally distributed random variables. For each sex-age group, the mean length of chinook salmon sampled by the tagging crews was compared to the mean length of the recreational harvest samples with a two-sample t-test (Zar 1974).

RESULTS

Abundance Estimate using Tagging Data

Tag Releases:

During the period 20 May through 11 August, 3,036 chinook salmon were tagged (Table 2). Although tagging continued until 11 August, only the 2,635 chinook salmon tagged and released between 20 May and 28 July were used for

Table 2. Tag releases by day and recoveries from each daily release for chinook salmon in the Kenai River, 1988.

Date of Release	Number Tagged	Out-of-System[1]	Adipose Clips[2]	Number Recovered[3]
20-May	32			2
21-May	46			5
22-May	13			
23-May	6			1
24-May	9			
25-May	15			
26-May	7			1
27-May	18			1
28-May	32			2
29-May	37			1
30-May				
31-May	38			1
01-June	21			1
02-June	56			1
03-June	41			3
04-June	77			4
05-June	49			1
06-June	20			1
07-June	45			3
08-June	44			
09-June	46			2
10-June	20		2	
11-June	16			1
12-June	11			1
13-June	18			1
14-June	33			
15-June	61		1	4
16-June	107			3
17-June	62		1	4
18-June	28	1 (K)	1	
19-June	48			
20-June	21			
21-June	26			1
22-June	47	1 (K)		1
23-June	30			
24-June	23			1
25-June	22			
26-June	29			1
27-June	22			
28-June	39			
29-June	28			
30-June	39			

-continued-

Table 2. Tag releases by day and recoveries from each daily release for chinook salmon in the Kenai River, 1988 (continued).

Date of Release	Number Tagged	Out-of-System[1]	Adipose Clips[2]	Number Recovered[3]
01-July	23			
02-July	13		1	1
03-July	27			
04-July				
05-July	46			1
06-July	20			1
07-July	66			2
08-July	25			2
09-July	47			
10-July	45	1 (CI)		2
11-July	52	1 (K)		1
12-July	76			1
13-July	40			1
14-July	75			2
15-July	55			
16-July	34			
17-July	48			1
18-July	71			1
19-July	78			
20-July	59			
21-July	85	1 (CD)		1
22-July	30			
23-July	20			
24-July	55			
25-July	43	1 (CI)		
26-July	34	1 (CS), 1 (CI)		
27-July	55	1 (CS)		
28-July	31	1 (CI)		
Subtotal	1,359	8	1	16
TOTAL[4]	2,635	10	6	61

-continued-

Table 2. Tag releases by day and recoveries from each daily release for chinook salmon in the Kenai River, 1988 (continued).

Date of Release	Number Tagged	Out-of-System[1]	Adipose Clips[2]	Number Recovered[3]
29-July	29	1 (CS)		
30-July	24		1	
31-July	18			
01-August	21			
02-August	44			
03-August	51			
04-August	54			
05-August	41			
06-August				
07-August				
08-August	34			
09-August	39			
10-August	28			
11-August	18			
GRAND TOTAL	3,036	11	7	61

1 Tags recovered outside the Kenai River:
CD = recovered in the commercial drift gill net fishery,
CS = recovered in the commercial set net fishery,
CI = carcass recovered on a Cook Inlet beach,
K = recovered in the Kasilof River.

2 Number of fish captured by the tagging crews with healed-over or missing adipose fins (not freshly clipped).

3 Recoveries from roving and access-site creel surveys only.

4 Total for the data included in the tagging estimate.

the abundance estimate. Because tag recovery ended on 31 July when the sport fishery closed, releases after 28 July were omitted to ensure that fish tagged during the last temporal stratum had approximately the same probability of recovery as earlier releases. The ending date of 28 July was selected because 46% of the tag recoveries by the creel surveys occurred within 3 days of the time of release (Figure 4).

Eleven chinook salmon tagged in the Kenai River were eventually recovered outside of the system: 3 in the Kasilof River; 1 in the commercial drift gill net fishery; 3 in the commercial set net fishery, and 4 tagged carcasses were found on the east beaches of Cook Inlet (Table 2). Tagged chinook salmon caught by the commercial fisheries in the marine waters outside of the Kenai River should not be interpreted as all being from systems other than the Kenai River. This group of fish probably does include fish from other systems and also Kenai River fish which backed out of the system (possibly due to the effects of tagging).

Seven chinook salmon with healed adipose finclips were captured during tagging. Heads were removed from these fish and stored for processing. Unfortunately, the heads were lost before the coded-wire tags were decoded.

Tag Recoveries:

During the period 20 May through 31 July, 1,858 chinook salmon were examined for tags and 61 tags were recovered by the creel surveys (Table 3 and Appendix Table 1). The majority of fish were examined by the access-site creel survey in the downstream area (1,739 chinook salmon examined). Five tags were recovered during the roving creel survey in the upstream section and 61 in the downstream survey. Because recovery rates of tags were not significantly different ($P > 0.10$) between the upstream and downstream creel surveys, the recovery data from both surveys were combined.

The first test comparing the length distribution of released tagged fish and tagged fish recaptured was not significant ($D=.0518$, $p=.99$) indicating the second sample (creel survey) is not size selective, and all sizes can be pooled for the abundance estimate. The second test was significant ($D=.0707$, $p=0.0004$) indicating that the first sample (tagging fishery) is size-selective (Figure 5). The age and length composition from the tagging fishery may not be representative of the population.

Abundance Estimate:

A summary of tag release and recovery data by bimonthly time periods shows that after June 16th the percent recovery by release stratum falls below 2%, and the tag-to-untagged ratios fall below 2% after July 1 (Table 4). Stratification schemes based on bimonthly periods could not be used. They did not meet the algebraic conditions of the estimation methods, as the probabilities of capture in one or more recapture strata were estimated to be negative. These periods were collapsed into 3 strata for further analysis.

The temporal strata were established so that the abundance of the May and June components of the early-run could be estimated separately from the late

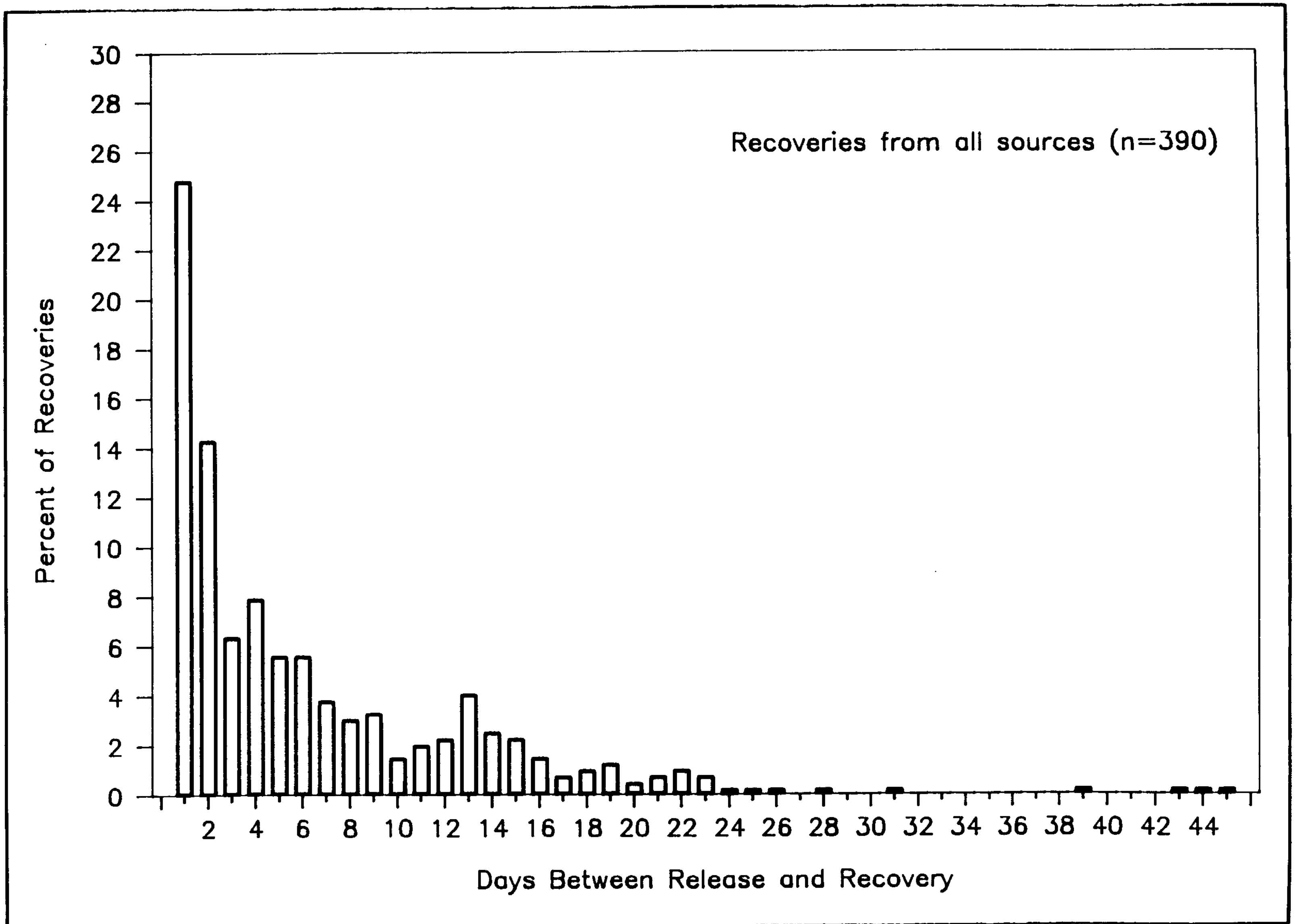


Figure 4. Number of days between tag release and recovery in the sport fishery for chinook salmon in the Kenai River, 1988.

Table 3. Recoveries of tagged chinook salmon by the upstream creel survey and the downstream access-site creel survey of the Kenai River recreational fishery, 1988.

Date	UPSTREAM CREEL SURVEY Number Examined	UPSTREAM CREEL SURVEY Number Recaptured	DOWNSTREAM ACCESS-SITE Number Examined	DOWNSTREAM ACCESS-SITE Number Recap.
20-May			4	
21-May			3	
22-May			28	3
23-May				
24-May			17	
25-May			9	1
26-May			19	1
27-May			21	2
28-May			33	
29-May			37	4
30-May			10	
31-May			5	
Subtotal			186	11
01-June			17	1
02-June			11	1
03-June			12	
04-June	1		41	
05-June			28	2
06-June				
07-June			5	
08-June			7	
09-June			15	1
10-June	4		30	2
11-June	1		34	2
12-June	2		38	2
13-June				
14-June		1	37	
15-June	4		47	4
16-June			48	1
17-June	3		37	4
18-June			25	2
19-June	4		42	5
20-June				
21-June			36	1
22-June	4		27	2
23-June	8	1	14	
24-June	16		7	
25-June	8		18	1
26-June	8		21	1
27-June				
Subtotal	63	2	597	32
28-June	12		54	
29-June			24	1
30-June			4	

-continued-

Table 3. Recoveries of tagged chinook salmon by the upstream creel survey and the downstream access-site creel survey of the Kenai River recreational fishery, 1988 (continued).

Date	UPSTREAM CREEL SURVEY Number Examined	UPSTREAM CREEL SURVEY Number Recaptured	DOWNSTREAM ACCESS-SITE Number Examined	DOWNSTREAM ACCESS-SITE Number Recap.
01-July	9		4	
02-July	4		4	
03-July	2		2	
04-July				
05-July	10		2	
06-July	5		29	
07-July			16	
08-July	4	1	21	1
09-July	1		22	
10-July	2	1	12	1
11-July				
12-July			90	1
13-July			31	
14-July			42	1
15-July	1		17	
16-July	2		22	1
17-July			21	
18-July				
19-July			25	1
20-July			19	
21-July			31	
22-July			80	2
23-July			99	1
24-July			80	1
25-July				
26-July			61	1
27-July			59	1
28-July	2	1	9	
Subtotal	54	3	880	13
29-July			5	
30-July	2		34	
31-July			37	
Subtotal	2		76	
TOTAL	119	5	1,739	61

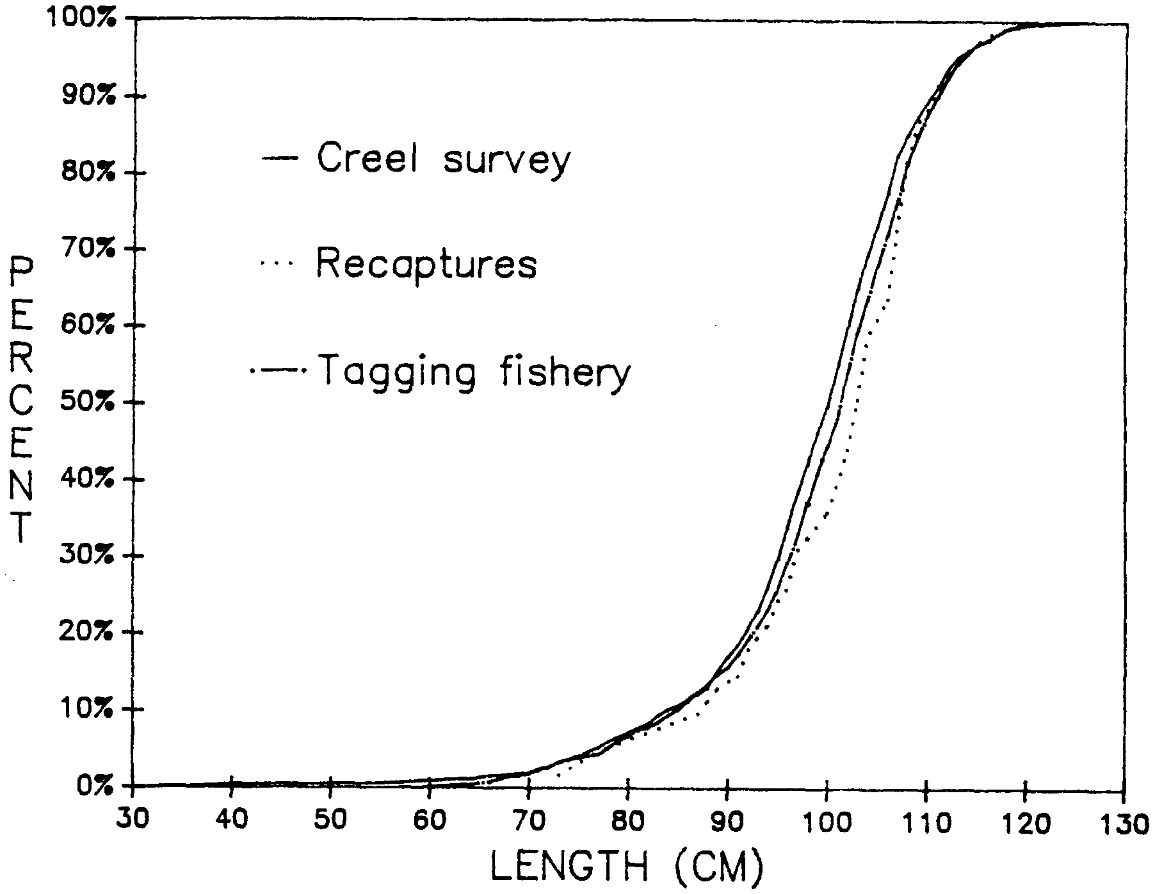


Figure 5. Percent cumulative length distributions of chinook salmon in the tagging experiment in the Kenai River 1988.

Table 4. Tag recovery summary by 2-weekly periods for chinook salmon in the Kenai River, 1988.

Release Period		Recovery Period 1	2	3	4	5	Total Recovery	Total Released	Percent Recovered
5/20-5/31	1	11	3				14	253	5.5
6/01-6/16	2		15	10	1		26	665	3.9
6/17-6/30	3			7	1		8	464	1.7
7/01-7/14	4				4	6	10	555	1.8
7/15-7/28	5					3	3	698	0.4
Tagged		11	18	17	6	9	61	2635	2.3
Examined		186	382	372	312	606	1858		
Untagged		175	364	355	306	597	1797		
% Tagged		6.3	4.9	4.8	2.0	1.5	3.4		

run. Of eight stratification schemes tested, one was selected in which three temporal strata were defined: (1) 20 May to 31 May; (2) 1 June to 30 June; and (3) 1 July to 28 July (Table 5). This stratification met the criterion that estimates for the early and late runs were separated at 1 July. The relative precision of the total estimate for this scheme was the lowest of the stratification schemes tested (Table 5). During the 1988 season, 28 June was the date chosen to separate the early and late runs. However stratification schemes using 28 June to separate the early and late runs did not have lower relative precision than the stratification chosen here (Table 5).

The chi-square tests comparing the frequency of tags recovered by release strata (columns A and B in Table 6) was significant when three release strata were chosen ($T=22.53$, $p<.005$), the rate of recovery decreased significantly for each strata. The tag-to-untagged ratios (Table 6) were not significant between recovery strata 1 and 2 ($X^2=0.52$, $p=0.5$) but these two strata were significantly different from the third ($X^2=16.08$, $p<0.005$). A Petersen estimate of abundance was not appropriate and the methods of Darroch (1961) were used. The estimated abundance for the early run (20 May through 1 July) was 25,047 chinook salmon (Table 7). The estimated number of chinook salmon <u>entering the Kenai River from 20 May through 28 July</u> was 113,335 fish. This estimate includes fish which are from the Kenai River system and those which have "strayed" into the river from non-Kenai systems.

The relative precision of the 95% confidence interval of the estimate for total run was 41% in 1988, with the relative precision at 79% for the first stratum, 44% for the second and 54% for the third (Table 7).

<u>Abundance Estimate using Gill Net Effort and Catch Data</u>,

For the combined data, three of the four statistics expressed as the mean for a crew-day during a stratum (SETS/CD, CAT/CD, SETS>0/CD) had the highest linear correlations with the estimated mean abundance of chinook salmon per day (Table 8). The catch per net-minute (CPUE), catch per set (MNCAT) and percent of total effort in net-minutes with catch (%EFF>0) had the next highest correlations.

Model Evaluation:

The power model for the statistic %EFF>0 (percent of total effort made up by sets with catch) had the second lowest mean squared errors of all of the models, but provided the smallest confidence intervals for the parameters estimated. This model was selected to estimate the number of chinook salmon entering the Kenai River from 29 July to 11 August. This statistic was also the one chosen in 1986 (Conrad and Larson 1987), while catch per crew-day (CATCD) was chosen in 1987 (Conrad 1988).

A plot of the residuals shows that the fit of the model is best at the lower values of the statistic, and that the five 1986 data points have smaller residuals compared to 1987 and 1988 (Figure 6).

Table 5. Estimates of the numbers of chinook salmon entering the Kenai River using different temporal stratifications of the tagging data, 1988.

STRATA Number	Definitions	TOTAL Estimate	SE[1]	EARLY RUN Estimate	SE	LATE RUN[2] Estimate	SE
3	Selected	113,335	23,541	25,047	4,777	88,288	24,126
3 E[3] E L	5/20-5/31 6/01-6/28 6/29-7/28	124,013	27,653	18,534	4,559	105,479	24,126
3 E E L	5/20-6/14 6/15-6/27 6/28-7/28	123,671	27,841	18,192	4,075	105,479	28,926
3	5/20-6/14 6/15-6/30 7/01-7/28	112,808	23,620	24,520	4,758	88,288	24,126
3 E E L	5/20-6/15 6/16-6/27 6/28-7/28	123,740	27,777	18,260	4,252	105,479	28,926
3	5/20-6/15 6/16-6/30 7/01-7/28	113,951	23,700	25,663	5,503	88,288	24,126
4 E E E L	5/20-5/31 6/01-6/15 6/16-6/27 6/28-7/28	123,645	27,842	18,166	4,178	105,479	28,926
4	5/20-5/31 6/01-6/15 6/16-6/30 7/01-7/28	113,444	23,696	25,156	5,515	88,288	24,126

1 SE = standard error.

2 Late run through 28 July only.

3 Run designation, E = early run and L = late run.

Table 6. Summary of tag releases and tag recoveries, by stratum, for chinook salmon in the Kenai River, 1988[1].

Stratum[2]		Tag Recoveries 1	2	3	(A) Number Recovered	(B) Not Recovered	Number Released	Percent Recovered
Tag Releases	1	11	3	0	14	239	253	5.5
	2	0	32	2	34	1,095	1,129	3.0
	3	0	0	13	13	1,240	1,253	1.0
(C) Tagged		11	35	15	61	2,574	2,635	
(D) Untagged		175	719	903	1,797			
Examined		186	754	918	1,858			
% Tagged		5.9	4.6	1.6				

1 The matrix defined by each of the four release and recovery strata corresponds to the M matrix; a diagonal matrix of the first four elements of row D is the Du matrix; and the column of Number Released is the vector a in Seber's (1982) notation.

2 Release and recovery strata:
1 = 20 May - 31 May,
2 = 1 June - 30 June,
3 = 1 July - 28 July (release) and 1 July - 31 July (recovery).

Table 7. Numbers of chinook salmon entering the Kenai River during each stratum estimated by analysis of the tagging data, 1988.

Stratum	Point Estimate	Standard Error[1]	95% Confidence Interval
1. 20 May - 31 May	2,882	1,165	598 - 5,165
2. 1 June - 30 June	22,165	4,966	12,432 - 31,898
Early Run Total	25,047	4,777	15,683 - 34,411
3. 1 July - 28 July	88,288	24,126	39,631 -134,440
Total Strata 1-3	113,335	23,541	64,559 -156,841

[1] Standard errors for the totals include covariance terms and are not simply the sum of the variances of the stratum estimates.

Table 8. Correlations between the estimates of mean abundance of chinook salmon per day for a stratum and the effort/catch statistics computed using charts from 1986, 1987 and 1988, separately and combined.

Statistic[1]		1986	1987	1988	Combined
1.	TOTSETS	0.897	0.927	0.583	0.398
2.	TOTEFF	-0.737	0.838	0.399	0.182
3.	TOTCAT	0.876	0.943	0.716	0.499
4.	MNDUR	-0.763	-0.891	-0.986	-0.639
5.	MNCAT	0.753	0.563	0.968	0.690
6.	CPUE	0.859	0.847	0.989	0.748
7.	TOTEFF=0	-0.777	0.647	0.014	-0.169
8.	MNDUR=0	-0.875	-0.607	-0.910	-0.711
9.	%EFF>0	0.860	0.468	0.953	0.742
10.	SETS>0	0.869	0.939	0.672	0.450
11.	%SETS>0	0.690	0.788	0.999	0.641
12.	MNDUR>0	-0.728	-0.925	-0.903	-0.595
13.	EFF/CD	-0.720	0.317	-0.067	-0.407
14.	CAT/CD	0.889	0.980	0.956	0.806
15.	SETS/CD	0.911	0.983	0.909	0.788
16.	SETS>0/CD	0.866	0.996	0.962	0.791

[1] see Table 1 for definitions of these statistics.

Abundance Estimate:

The nonlinear, least-squares parameter estimates for the power model using the statistic %EFF>0 resulted in the following model (Figure 6):

$$Y = 10065.6\ (\%EFF>0)^{5.97} \qquad [8]$$

where, Y is the estimated mean abundance of chinook salmon per day. For stratum 4, %EFF>0 = 73.6% which results in an estimate of mean abundance of 1,612.9 chinook salmon per day for stratum 4. The empirical estimate of the standard error for this estimate from the Monte Carlo simulation is 506. For the 14 days from 29 July through 11 August, this gives an estimated total abundance of 22,581 chinook salmon with a standard error of 7,078 and a relative precision of 61%.

Summary

Combining the strata for estimates of early and late runs gives an early run total of 25,047 fish (SE=4,777) and a relative precision of 37%, and a late run of 110,869 chinook salmon (SE=25,143) with a relative precision of 44% (Table 9). The total run to enter the Kenai River 20 May through 11 August is estimated at 135,916 (SE=24,582) with a relative precision of 35%.

Biological Data

Gill Net Samples:

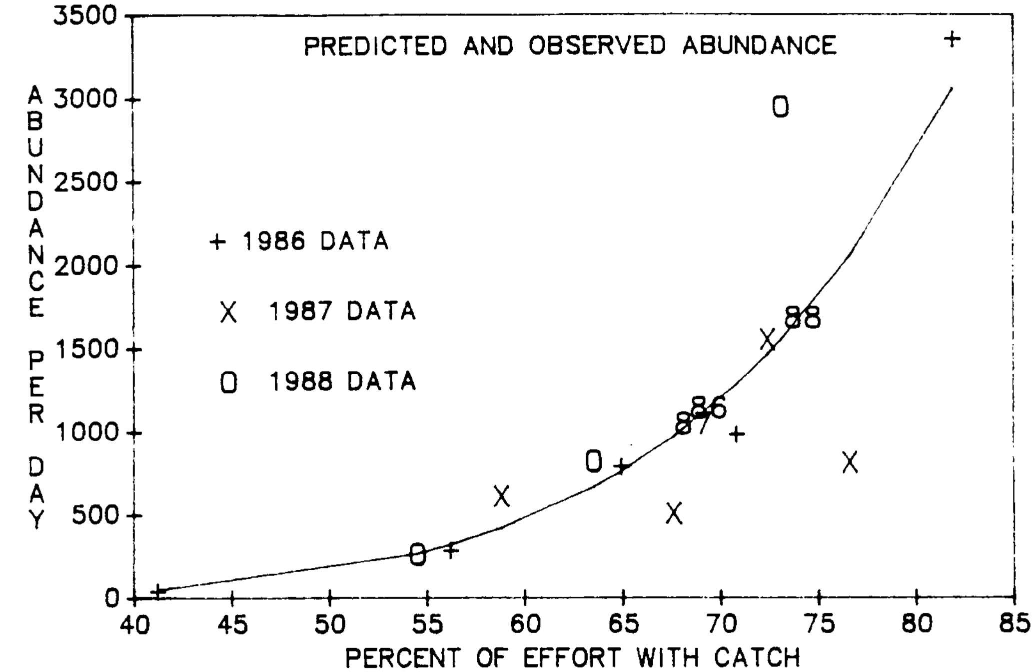
Age 1.3 and age 1.4 chinook salmon composed 15.7% and 71.5% of the early run, respectively, and 3.8% and 77.7% of the late run, respectively (Table 10). Age 1.4 female chinook salmon were the most abundant sex-age group in both the early run (42.2%) and the late run (47.1%).

The age compositions of male chinook salmon sampled by the tagging crews changed temporally ($P < 0.005$) within both the early and late runs (Appendix Table 2). There were no significant temporal changes in the age composition of females during either run ($P > 0.05$). Age 1.4 fish composed the most abundant age group for both sexes in every stratum (Appendix Table 2).

The mean lengths by age and sex of the chinook salmon sampled during the late run were larger than those sampled during the early run (Table 11). Age 1.3 females were larger than age 1.3 males, while age 1.4 and age 1.5 males were larger than age 1.4 and age 1.5 females in every time period (Appendix Table 3). This size relationship was similar in 1986 (Conrad and Larson 1987) and 1987 (Conrad 1988).

Spawning Escapement:

Spawning ground samples were taken over 6 days, four in lower river reaches (up to Soldotna, RM 22) and two in the upper reaches. Age compositions differ significantly between these two areas for males (P=0.06) and females (P=0.01), but not among sample dates within the two areas (P>0.10). The majority of the scale samples were age 1.4 (Table 12), but the percentage of



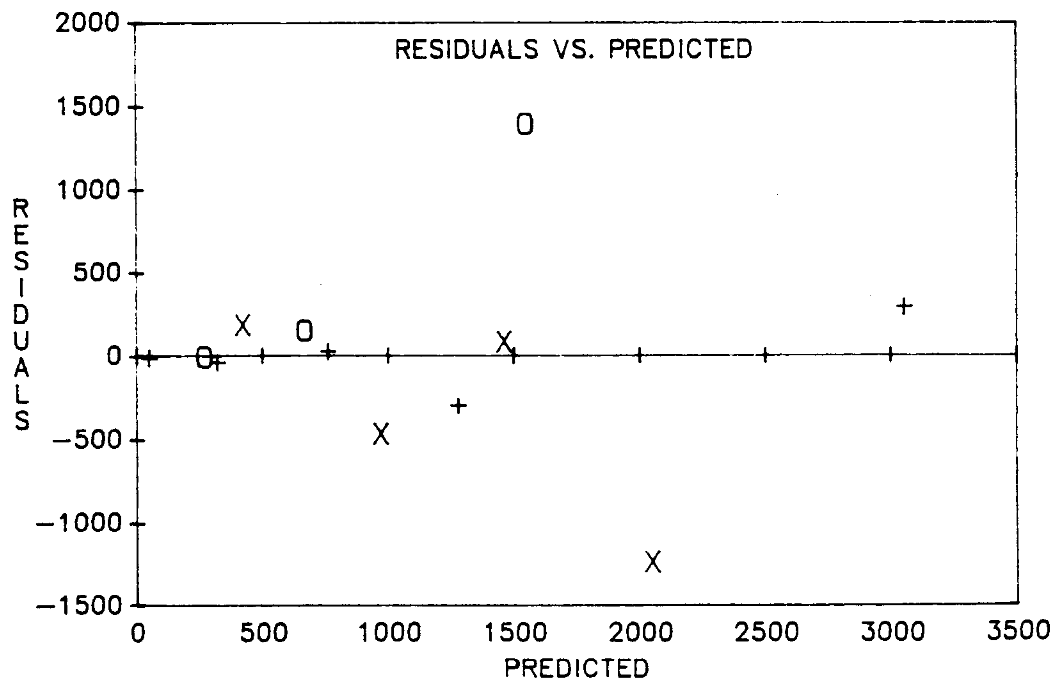


Figure 6. Catch statistic (%EFF>0) versus the estimated mean abundance of chinook salmon per day for strata in 1986, 1987 and 1988 and the model used to estimate the abundance for stratum 5 (29 July to 11 August) in 1987.

Table 9. Estimated numbers of chinook salmon, by stratum, entering the Kenai River, 1988.

Stratum	Point Estimate	Standard Error	95% Confidence Interval
1. 20 May-31 May	2,882	1,165	598- 5,165
2. 1 June-30 June	22,165	4,966	12,432- 31,898
Early Run total	25,047	4,777	15,683- 34,411
3. 1 July-28 July	88,288	24,126	39,631-134,440
4. 29 July-11 August	22,581	7,078	8,078- 36,454
Late Run total	110,869	25,143	61,589-160,149
Total Stratum 1-4	135,916	24,582	87,735-184,097

Table 10. Age group composition of early and late run chinook salmon caught by drift gill nets in the Kenai River, 1988.

			Age Group					
Component	Sex	Statistic	1.2	1.3	1.4	1.5	Other[1]	TOTAL
EARLY RUN 5/20 - 6/30	Female	Sample Size		47	329	18		394
		% of Sample		6.0	42.2	2.3		50.6
		Std. Error		0.85	1.77	0.54		1.79
	Male	Sample Size	14	75	228	65	3	385
		% of Sample	1.8	9.6	29.3	8.3	0.4	49.4
		Std. Error	0.54	1.06	1.63	0.99	0.22	1.79
	Combined	Sample Size	14	122	557	83	3	779
		% of Sample	1.8	15.7	71.5	10.7	0.4	100.0
		Std. Error	0.48	1.30	1.62	1.11	0.22	
LATE RUN 7/01 - 8/11	Female	Sample Size		9	441	48		498
		% of Sample		1.0	47.1	5.1		53.1
		Std. Error		0.32	1.63	0.72		1.63
	Male	Sample Size	12	27	287	113		439
		% of Sample	1.3	2.9	30.6	12.1		46.9
		Std. Error	0.37	0.55	1.51	1.06		1.63
	Combined	Sample Size	12	36	728	161		937
		% of Sample	1.3	3.8	77.7	17.2		100.0
		Std. Error	0.37	0.63	1.36	1.23		
SEASON TOTAL 5/20 - 8/11	Female	Sample Size		56	770	66		892
		% of Sample		3.3	44.9	3.8		52.0
		Std. Error		0.43	1.20	0.46		1.21
	Male	Sample Size	26	102	515	178	3	824
		% of Sample	1.5	5.9	30.0	10.4	0.2	48.0
		Std. Error	0.29	0.57	1.11	0.74	0.10	1.21
	Combined	Sample Size	26	158	1,285	244	3	1,716
		% of Sample	1.5	9.2	74.9	14.2	0.2	100.0
		Std. Error	0.29	0.70	1.05	0.84	0.10	

[1] Age groups 1.6 and 2.3 combined.

Table 11. Mean length (mm), by sex and age group, of early and late run chinook salmon caught by drift gill nets in the Kenai River, 1988.

			Age Group						
Component	Sex	Statistic	1.2	1.3	1.4	1.5	1.6	2.3	TOTAL
EARLY RUN	Female	Sample Size		47	329	18			394
5/20 - 6/30		Mean Length		812	970	1,044			954
		Std. Error		0.86	0.38	1.50			0.44
	Male	Sample Size	14	75	228	65	2	1	385
		Mean Length	651	763	1,022	1,097	1,215	760	971
		Std. Error	0.79	0.74	0.56	0.60	1.50		0.76
	Combined	Sample Size	14	122	557	83	2	1	779
		Mean Length	651	782	991	1,085	1,215	760	962
		Std. Error	0.79	0.60	0.34	0.62	1.50		0.44
LATE RUN	Female	Sample Size		9	441	48			498
7/01 - 8/11		Mean Length		869	1,003	1,063			1,007
		Std. Error		1.41	0.26	0.86			0.27
	Male	Sample Size	12	27	287	113			439
		Mean Length	682	811	1,044	1,119			1,039
		Std. Error	0.94	1.36	0.42	0.43			0.54
	Combined	Sample Size	12	36	728	161			937
		Mean Length	682	826	1,019	1,103			1,022
		Std. Error	0.94	1.15	0.24	0.44			0.29
SEASON TOTAL	Female	Sample Size		56	770	66			892
5/20 - 8/11		Mean Length		821	989	1,058			983
		Std. Error		0.80	0.23	0.75			0.26
	Male	Sample Size	26	102	515	178	2	1	824
		Mean Length	665	776	1,034	1,111	1,215	760	1,007
		Std. Error	0.67	0.68	0.35	0.36	1.50		0.47
	Combined	Sample Size	26	158	1,285	244	2	1	1,716
		Mean Length	665	792	1,007	1,097	1,215	760	995
		Std. Error	0.67	0.55	0.20	0.36	1.50		0.26

Table 12. Estimated age composition of chinook salmon sampled during surveys of spawning grounds on the mainstem of the Kenai River, 1988.

Dates	Sex	Statistic	Age Group 1.2	1.3	1.4	1.5	Total
9/19-9/26 (Lower Reach)	Female	Percent	0	4.4	46.4	3.3	54.2
		Standard error	0	1.1	2.6	0.9	2.6
	Male	Percent	0.3	1.9	34.4	9.2	45.8
		Standard error	0.3	0.7	2.5	1.5	2.6
		Combined Percent	0.3	6.4	80.8	12.5	
		Standard error	0.3	1.3	2.1	1.7	
9/27-9/28 (Upper Reach)	Female	Percent	0	1.4	45.2	11.0	57.5
		Standard error	0	1.4	5.8	3.6	5.8
	Male	Percent	0	2.7	23.3	16.4	42.5
		Standard error	0	1.8	4.9	4.3	5.8
		Combined Percent	0	4.1	68.5	27.4	
		Standard error	0	2.3	5.4	5.2	

age 1.5 was higher for males than females, and the percentage of age 1.5 was higher in the upper reaches compared to the lower river (Table 12). No significant differences were found between mean lengths between the two areas (Table 13).

DISCUSSION

The sonar estimates were lower than the tagging estimates (Table 14), the only exception being in the first stratum. The early run sonar estimates did fall within the 95% confidence interval (CI) of the tagging estimates for both strata and for the total. However this was not the case for the late run except in the last stratum. The sonar estimate was below the 95% CI both for the late run total and the total run (early+late). The total difference between the two estimates represents 86% of the sonar estimate. In 1987, the first year where full estimates are available using both methods, the discrepancy between the two estimates was 17%. Assuming that the abundance estimate from the sonar project is unbiased, two possible reasons why the estimate from the tagging project is higher are: loss of tagged fish and imprecision in the estimate from the tagging project.

In previous years, loss of tags by chinook salmon tagged by the gill net crews has been observed to be very small (less than 0.5%). There is no direct evidence of natural tag loss in 1988. However, three tags were recovered during the creel surveys that had been removed from tagged fish that had been caught and released. This does violate the assumption that tags are not selectively removed from tagged fish, but because no tagging wounds were observed during creel surveys, it is assumed that this practice is somewhat limited.

As was found in 1985, 1986, and 1987 (Conrad and Larson 1987, Conrad 1988), small numbers of chinook salmon tagged in the lower Kenai River were recovered in other systems in 1988. The only out-of-system recoveries in 1988 were from the Kasilof River; which had 11 recoveries in 1985, 5 recoveries in 1986 and 3 recoveries in 1987. Tags have also been recovered from the Susitna River (1 in 1985, 2 in 1986) and Deep Creek (1 in 1985). In 1986, 676 chinook salmon from Crooked Creek hatchery were estimated to be present in the lower Kenai River from 17 May to 30 June from analysis of coded-wire tag data (Conrad and Larson 1987). Because of the proximity of the Kasilof River to the Kenai River, it has been assumed that more fish from this stock are present in the lower Kenai River than any other stock. However, any fish that wandered into, and then out of the Kenai River would also bias the sonar estimate upwards, as the counter does not distinguish between upward and downward movement.

The imprecision of the tagging estimate of abundance in 1988 (relative precision of 95% confidence interval = 36%) was substantially higher than in 1987 (21%) and 1986 (27%). The relative precision was 37% for the early run, while it was 52% for the late run tagging strata and 44% for the total late run including the first 2 weeks of August. The reason for the imprecision is to be found in the number of tags released and number of fish examined

Table 13. Mean length (mm), by sex and age group, of chinook salmon sampled during surveys of spawning grounds on the mainstem of the Kenai River, 1988.

			Age Group			
Dates	Sex	Statistic	1.2	1.3	1.4	1.5
9/19 - 9/26	Male	Mean Length	740	827	1,003	1,103
		Sample Size	1	7	124	33
		Standard Error		22	5	8
	Female	Mean Length		856	974	1,027
		Sample Size		16	167	12
		Standard Error		9	4	18
9/27 - 9/29						
Male	Male	Mean Length		850	1,011	1,085
		Sample Size		1	17	12
		Standard Error			13	20
	Female	Mean Length		870	987	1,019
		Sample Size		1	33	8
		Standard Error			8	21

Table 14. Comparison of estimated abundance of chinook salmon and sonar estimates by strata, 1988

Stratum	Tagging Point Estimate	95% Confidence Interval	Sonar Estimates	Percent Difference[1]
1. 5/20-5/31	2,882	598- 5,165	5,574	48%
2. 6/01-6/30	22,165	12,432- 31,898	15,306	-45%
Early Run	25,047	15,683- 34,411	20,880	-20%
3. 7/01-7/28	88,288	39,631-134,440	36,677	-141%
4. 7/29-8/11 2	22,581	8,708- 36,454	15,331	-47%
Late Run	110,869	61,589-160,149	52,008	-113%
Total	135,916	87,735-184,097	72,888	-86%

[1] $\text{Percent difference} = \dfrac{\text{Sonar Estimate - Tag Estimate}}{\text{Sonar Estimate}}$

[2] Abundance estimated from gill net fishery.

relative to the large population size. The rate of recovery drops significantly across the release strata, from 5% for May and 3% in June to 1% in July. During the late run, the number of days with tag releases from which no recoveries were made at all increased from 35% to 57% of tagging days (Table 2). In the Kenai River creel survey (Hammarstrom in press), the total number of interviews conducted and the number of fish examined during the late run (4,943 interviews upstream and down, with 918 fish examined and 15 tags recovered) was lower than the early run (5,209 interviews, with 940 fish examined and 46 tags recovered). Assuming that the population size in July was at 80,000 chinook salmon, then in order to achieve a relative precision of 30%, the number of fish released or the number examined for tags would have had to be doubled. Doubling both sample sizes would provide an improvement down to 20%. However, increasing the effort in the tagging fishery is not a feasible solution, as interference between the tagging crews and sport fishermen is already a problem, particularly during the late run and daily catch rates suggest that efficiency decreases in the tagging fishery with increasing fish abundance. Therefore it is recommended that catch sampling be increased during the fishery on the late run of Kenai chinook salmon.

The estimate of abundance in the last stratum (28 July to 11 August) using gill net fishery data was necessary in the absence of tag recovery data for that period. Also, the 3 separate years were combined for the analysis, again of necessity, although in reality the trends for the individual years are different (Figure 6). This is probably not the best method of estimating the abundance in the last stratum. Since tagging efforts were continued after 28 July, the possibility exists to also incorporate continued tag recovery efforts in the project. This would allow an estimate of abundance from tagging data.

RECOMMENDATIONS

1. The sample design for collecting biological data (sex, age, and length data) from chinook salmon by the tagging crews and creel surveys should be temporally stratified as there are significant changes during the return. The approximate 15-day periods used in the years 1986, 1987, and 1988 are recommended.

2. Tag recovery efforts in the creel survey should be increased in order to increase the rate of recovery of tags and improve the precision levels.

3. In order to estimate abundance of the last stratum, tag recoveries should be obtained after the closure of the fishery through a gill net fishery located upriver of the tagging fishery.

ACKNOWLEDGEMENTS

Steve Hammarstrom was the project leader for this project. Under his supervision, all aspects of this project were effectively and efficiently executed. The leaders of the gill net tagging crews are thanked for their dedication and hard work: Mary King, Mary Whalen, Kent Bovee, and Larry DuBois; as are their assistants: John Roemer, Beth Lenart, Jerry Strait, and Pam Pomeroy. Also, thanks are extended to the individuals conducting the various creel surveys: Jim Gebhard, Ty Traughber, Allison Butler, Laurie Flagg, Jeff Nelson, and Gino Del Frate. Larry Marsh managed much of the data in-season and assisted with post-season data summary and analysis.

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APPENDIX TABLES

Appendix Table 1. Detailed release and recovery information for the 61 tags recovered from chinook salmon during creel surveys of the Kenai River, 1988.

Tag Number	Tag Color	Date Tagged	Date Recover.	Days Out	Recovery Source[1]	Mile Tagged	Mile Recover.	Miles Between
9456	green	20-May	22-May	2	ASS	9.0	12.3	3.3
9460	green	20-May	22-May	2	ASS	8.5	10.1	1.6
9482	green	21-May	22-May	1	ASS	9.2	10.6	1.4
9477	green	21-May	29-May	8	ASS	7.9	16.5	8.6
9555	green	21-May	26-May	5	ASS	8.1	11.1	3.0
9478	green	21-May	06-June	12	ASS	7.5	10.1	2.6
9484	green	21-May	25-May	4	ASS	9.2	11.4	2.2
9316	green	23-May	27-May	4	ASS	8.6	14.3	5.7
9329	green	26-May	27-May	1	ASS	7.9	14.2	6.3
9586	green	27-May	29-May	2	ASS	9.3	14.4	5.1
9494	green	28-May	29-May	1	ASS	7.4	13.6	6.2
9341	green	28-May	29-May	1	ASS	9.0	14.3	5.3
9416	green	29-May	14-June	16	URS	8.4	42.5	34.1
9621	green	31-May	01-June	1	ASS	7.4	13.6	6.2
678	white	01-June	15-June	14	ASS	7.3	16.5	9.2
729	white	02-June	05-June	3	ASS	7.3	16.0	8.7
851	white	03-June	22-June	19	ASS	7.5		
774	white	03-June	09-June	6	ASS	8.3	18.5	10.2
780	white	03-June	10-June	7	ASS	7.4	13.6	6.2
916	white	04-June	05-June	1	ASS	7.4	11.4	4.0
921	white	04-June	18-June	14	ASS	8.6	18.5	9.9
877	white	04-June	12-June	8	ASS	8.1	13.6	5.5
956	white	04-June	17-June	13	ASS	8.6	13.6	5.0
929	white	05-June	10-June	5	ASS	7.9	22.9	15.0
11002	white	06-June	23-June	17	URS	7.9	44.0	36.1
11036	white	07-June	11-June	4	ASS	6.9	22.9	16.0
11029	white	07-June	12-June	5	ASS	7.0	15.3	8.3
812	white	07-June	19-June	12	ASS	7.0	11.4	4.4
11070	white	09-June	11-June	2	ASS	6.8	18.5	11.7
11172	white	09-June	16-June	7	ASS	7.3	11.4	4.1
11093	white	11-June	15-June	4	ASS	7.4	22.9	15.5
11200	white	12-June	15-June	3	ASS	7.2	22.9	15.7
11109	white	13-June	08-July	25	URS	9.4	44.5	35.1
12001	orange	15-June	17-June	2	ASS	7.8	17.6	9.8
8728	orange	15-June	19-June	4	ASS	8.8		
8388	orange	15-June	17-June	2	ASS	7.1	14.3	7.2
8701	orange	15-June	15-June	0	ASS	9.3	10.5	1.2
8591	orange	16-June	17-June	1	ASS	8.8	14.3	5.5
12024	orange	16-June	21-June	5	ASS	7.8	16.2	8.4
8564	orange	16-June	22-June	6	ASS	8.9		
8866	orange	17-June	18-June	1	ASS	9.1	18.5	9.4

-continued-

Appendix Table 1. Detailed release and recovery information for the 61 tags recovered from chinook salmon during creel surveys of the Kenai River, 1988 (continued).

Tag Number	Tag Color	Date Tagged	Date Recover.	Days Out	Recovery Source[1]	Mile Tagged	Mile Recover.	Miles Between
8858	orange	17-June	19-June	2	ASS	9.2	13.6	4.4
8649	orange	17-June	19-June	2	ASS	7.3	11.4	4.1
8875	orange	17-June	19-June	2	ASS	9.1	10.1	1.0
8940	orange	21-June	26-June	5	ASS	8.3	12.2	3.9
12172	orange	22-June	10-July	18	URS	7.9	45.8	37.9
8994	orange	24-June	25-June	1	ASS	7.8	14.5	6.7
12317	orange	26-June	29-June	3	ASS	9.1	10.1	1.0
1556	yellow	02-July	28-July	26	URS	6.4	46.0	39.6
1572	yellow	05-July	12-July	7	ASS	6.6		
1594	yellow	06-July	10-July	4	ASS	9.4	11.4	2.0
1789	yellow	07-July	08-July	1	ASS	6.6	7.5	0.9
1870	yellow	07-July	14-July	7	ASS	7.1	18.5	11.4
13031	yellow	11-July	22-July	11	ASS	6.9	14.3	7.4
1992	yellow	12-July	23-July	11	ASS	9.4	11.4	2.0
13216	yellow	13-July	26-July	13	ASS	6.9	14.4	7.5
13104	yellow	14-July	19-July	5	ASS	8.7	18.5	9.8
13284	yellow	14-July	16-July	1	ASS	7.3	11.4	4.1
2980	blue	17-July	22-July	5	ASS	9.4	10.1	0.7
14507	blue	18-July	27-July	9	ASS	7.9		
14590	blue	21-July	24-July	3	ASS	9.0	8.0	

1 Recovery sources: URS = upstream roving creel survey, and
ASS = access-site creel survey.

Appendix Table 2. Age group composition of chinook salmon caught by drift gill nets in the Kenai River, 1988.

			Age Group					
Stratum	Sex	Statistic	1.2	1.3	1.4	1.5	Other[1]	TOTAL
5/20 - 5/31	Female	Sample Size		7	93	5		105
		% of Sample		3.7	48.7	2.6		55.0
		Std. Error		1.36	3.63	1.16		3.61
	Male	Sample Size		9	49	26	2	86
		% of Sample		4.7	25.7	13.6	1.0	45.0
		Std. Error		1.54	3.17	2.49	0.74	3.61
	Combined	Sample Size		16	142	31	2	191
		% of Sample		8.4	74.3	16.2	1.0	100.0
		Std. Error		2.01	3.17	2.68	0.74	
6/01 - 6/15	Female	Sample Size		25	134	4		163
		% of Sample		7.1	37.9	1.1		46.0
		Std. Error		1.36	2.58	0.56		2.65
	Male	Sample Size	9	54	101	26	1	191
		% of Sample	2.5	15.3	28.5	7.3	0.3	54.0
		Std. Error	0.84	1.91	2.40	1.39	0.28	2.65
	Combined	Sample Size	9	79	235	30	1	354
		% of Sample	2.5	22.3	66.4	8.5	0.3	100.0
		Std. Error	0.84	2.22	2.51	1.48	0.28	
6/16 - 6/30	Female	Sample Size		15	102	9		126
		% of Sample		6.4	43.6	3.8		53.8
		Std. Error		1.60	3.25	1.26		3.27
	Male	Sample Size	5	12	78	13		108
		% of Sample	2.1	5.1	33.3	5.6		46.2
		Std. Error	0.95	1.45	3.09	1.50		3.27
	Combined	Sample Size	5	27	180	22		234
		% of Sample	2.1	11.5	76.9	9.4		100.0
		Std. Error	0.95	2.09	2.76	1.91		

- Continued -

Appendix Table 2. Age group composition of chinook salmon caught by drift gill nets in the Kenai River, 1988 (continued).

Stratum	Sex	Statistic	1.2	1.3	1.4	1.5	Other[1]	TOTAL
			Age Group					
7/01 - 7/15	Female	Sample Size		5	203	22		230
		% of Sample		1.0	41.5	4.5		47.0
		Std. Error		0.46	2.23	0.94		2.26
	Male	Sample Size	7	16	188	48		259
		% of Sample	1.4	3.3	38.4	9.8		53.0
		Std. Error	0.54	0.81	2.20	1.35		2.26
	Combined	Sample Size	7	21	391	70		489
		% of Sample	1.4	4.3	80.0	14.3		100.0
		Std. Error	0.54	0.92	1.81	1.59		
7/16 - 7/31	Female	Sample Size		2	160	16		178
		% of Sample		0.7	52.8	5.3		58.7
		Std. Error		0.47	2.87	1.29		2.83
	Male	Sample Size	5	10	72	38		125
		% of Sample	1.7	3.3	23.8	12.5		41.3
		Std. Error	0.73	1.03	2.45	1.91		2.83
	Combined	Sample Size	5	12	232	54		303
		% of Sample	1.7	4.0	76.6	17.8		100.0
		Std. Error	0.73	1.12	2.44	2.20		
8/01 - 8/11	Female	Sample Size		2	78	10		90
		% of Sample		1.4	53.8	6.9		62.1
		Std. Error		0.97	4.15	2.11		4.04
	Male	Sample Size		1	27	27		55
		% of Sample		0.7	18.6	18.6		37.9
		Std. Error		0.69	3.24	3.24		4.04
	Combined	Sample Size		3	105	37		145
		% of Sample		2.1	72.4	25.5		100.0
		Std. Error		1.19	3.72	3.63		

[1] Age groups 1.6 and 2.3 combined.

Appendix Table 3. Mean length (mm) by sex and age group of chinook salmon caught by drift gill nets in the Kenai River, 1988.

			Age Group						
Stratum	Sex	Statistic	1.2	1.3	1.4	1.5	1.6	2.3	TOTAL
5/20 - 5/31	Female	Sample Size		7	93	5			105
		Mean Length		791	975	1,056			967
		Std. Error		10.3	5.8	21.6			7.2
	Male	Sample Size		9	49	26	2		86
		Mean Length		770	1,023	1,094	1,215		1,022
		Std. Error		17.7	8.9	9.2	15.0		12.0
	Combined	Sample Size		16	142	31	2		191
		Mean Length		779	992	1,087	1,215		992
		Std. Error		11.0	5.2	8.7	15.0		7.0
6/01 - 6/15	Female	Sample Size		25	134	4			163
		Mean Length		804	953	1,045			932
		Std. Error		13.7	5.0	18.5			6.4
	Male	Sample Size	9	54	101	26		1	191
		Mean Length	640	758	1,009	1,094		760	931
		Std. Error	10.4	7.9	8.1	8.8			11.3
	Combined	Sample Size	9	79	235	30		1	354
		Mean Length	640	773	977	1,088		760	932
		Std. Error	10.4	7.3	4.9	8.5			0.68
6/16 - 6/30	Female	Sample Size		15	102	9			126
		Mean Length		834	987	1,037			972
		Std. Error		12.3	8.3	27.5			8.5
	Male	Sample Size	5	12	78	13			108
		Mean Length	672	782	1,037	1,107			1,000
		Std. Error	3.7	27.0	11.0	16.5			13.9
	Combined	Sample Size	5	27	180	22			234
		Mean Length	672	811	1,008	1,078			985
		Std. Error	3.7	14.5	7.0	16.3			7.9

- Continued -

Appendix Table 3. Mean length (mm) by sex and age group of chinook salmon caught by drift gill nets in the Kenai River, 1988 (continued).

			Age Group						
Stratum	Sex	Statistic	1.2	1.3	1.4	1.5	1.6	2.3	TOTAL
7/01 - 7/15	Female	Sample Size		5	203	22			230
		Mean Length		866	1,009	1,066			1,011
		Std. Error		18.6	3.9	12.5			4.1
	Male	Sample Size	7	16	188	48			259
		Mean Length	676	796	1,050	1,119			1,037
		Std. Error	15.1	18.4	5.3	6.5			7.1
	Combined	Sample Size	7	21	391	70			489
		Mean Length	676	812	1,029	1,102			1,025
		Std. Error	15.1	16.0	3.4	6.6			4.3
7/16 - 7/31	Female	Sample Size		2	160	16			178
		Mean Length		845	996	1,065			1,001
		Std. Error		15.0	4.3	11.6			4.5
	Male	Sample Size	5	10	72	38			125
		Mean Length	690	833	1032	1117			1028
		Std. Error	0.84	2.07	0.86	0.78			1.07
	Combined	Sample Size	5	12	232	54			303
		Mean Length	690	835	1,007	1,102			1,012
		Std. Error	8.4	18.0	4.1	7.2			5.2
8/01 - 8/11	Female	Sample Size		2	78	10			90
		Mean Length		900	1,102	1,056			1,055
		Std. Error		10.0	5.9	25.9			6.3
	Male	Sample Size		1	27	27			55
		Mean Length		840	1,042	1,123			1,078
		Std. Error			10.3	8.7			9.6
	Combined	Sample Size		3	105	37			145
		Mean Length		880	1,012	1,105			1,033
		Std. Error		20.8	5.4	10.5			6.1

APPENDIX A

Three possible sources of variation for each of the 17 effort/catch statistics having between-crew and between-day variation were investigated: (1) between-set variation for sets made on the same day by the same crew; (2) between-crew variation; and (3) between-day variation. The possible sources of variation contributing to each of the statistics are summarized in Appendix Table A1. Four of the statistics have between-day variation only.

In 1988, tagging was carried out on 84 tides and 3,468 sets were made. The majority of the tides were fished by two crews (72 tides), while three crews fished on 12 tides, four crews on one tide, and one crew on one tide.

Methods

Two-factor analysis of variance (ANOVA) was used to analyze those variables which had between-set variation. Two-factor ANOVA for unequal number of observations in each cell was conducted using a regression approach to test the significance of interaction of the factors and the main-effects. If the interaction was not significant (α=0.01), the significance of the main effects (crew and tide) was tested using a reduced model, where the interaction was combined into the error term (Kleinbaum and Kupper 1978). Separate analyses of the gill net effort and chinook salmon catch statistics were conducted for tides when only two crews fished and for tides when only three crews fished so that a complete-block design could be used. All ANOVA were conducted with SAS (1982).

Those variables in Appendix Table A1 with only crew and day as sources of variation, but no variation between sets, were tested to determine if there were significant differences among crews on tides when multiple crews operated. On tides when only two crews operated, the nonparametric Wilcoxon 2-sample test (Conover 1980) for two related samples was used. The k sample extension of the Wilcoxon test, the Kruskal-Wallis test (Conover 1980), was used for tides when three crews operated. For these tests, crews corresponded to the treatments and tides (days) to the blocks in the experimental design.

Results

The crew-day interactions were significant for four of the 10 comparisons (Appendix Table A2). Interaction terms are difficult to interpret and the presence of significant interaction nullifies any tests of the main-effects (Kleinbaum and Kupper 1978). The day effect was significant ($P < 0.05$) in all analyses where the interaction effect was not significant ($P > 0.05$). The crew effect was significant ($P < 0.01$) in two of the six analyses with no significant interaction effect.

The results of the nonparametric tests for differences among-crews for the eight statistics having two sources of variation were similar to those of the two-factor ANOVA. No significant difference ($P < 0.05$) was found for the comparison of data collected during two-crew or three-crew tides (Appendix Table A3).

Discussion

There was no evidence of gear competition between crews as was found in 1986 (Conrad and Larson 1987). Therefore, we used all effort and catch data in the regression analyses.

Since there were no significant among-crew differences for the effort and catch statistics from tides when three or fewer crews worked (Appendix Table A3), data were pooled for all crews. Because crews were not a significant source of variation, a two-stage sample design was used to estimate the variance of the statistics measured by set.

Appendix Table A1. Possible sources of variation for the 17 effort and catch statistics investigated.

Statistic[1]	Sources of Variation
TOTSETS	crew, day
TOTEFF	crew, day
MNDUR	set, crew, day
TOTCAT	crew, day
MNCAT	set, crew, day
MNCPUE	set, crew, day
CPUE	crew,day
TOTEFF=0	crew, day
MNDUR=0	set, crew, day
%EFF>0	crew, day
SETS>0	crew, day
%SETS>0	crew, day
MNDUR>0	set, crew, day
SETS/CD	day
EFF/CD	day
CAT/CD	day
SETS>0/CD	day

[1] Statistics defined in Table 1.

Appendix Table A2. Results of the two-factor analyses of variance for the effort and catch statistics having three sources of variation: set, crew, and day. Analyses performed for tides when only two crews worked and tides when three crews worked. (** = significant $P \le 0.01$, * = significant $0.01 < P \le 0.05$, and NS = not significant $P > 0.05$).

	Two Crews			Three Crews		
Statistic[1]	Int[2]	Day	Crew	Int[2]	Day	Crew
MNDUR[3]	**	**	*	NS	**	NS
MNCAT[3]	**	**	NS	NS	**	**
MNCPUE[3]	**	**	NS	NS	**	**
MNDUR=0[3]	NS	**	NS	NS	*	NS
MNDUR>0[3]	**	**	*	NS	**	NS

[1] Statistics defined in Table 1.
[2] Day-crew interaction.
[3] Transformed by natural logarithm to equalize variances.

Appendix Table A3. Results of the non-parametric tests for related samples of effort and catch statistics having two sources of variation: crew and day. Analyses performed for tides when only two crews worked and tides when three crews worked. (** = significant $P \leq 0.01$, * = significant $0.01 < P \leq 0.05$, and NS = not significant $P > 0.05$).

Statistic[1]	Two Crews	Three Crews
TOTSETS	NS	NS
TOTEFF	NS	NS
TOTCAT	NS	NS
CPUE	NS	NS
TOTEFF=0	NS	NS
%EFF>0	NS	NS
SETS>0	NS	NS
%SETS>0	NS	NS

[1] Statistics defined in Table 1.